

Benchmarking:

What's Your Building's Energy IQ?

Evan Mills, Ph.D.

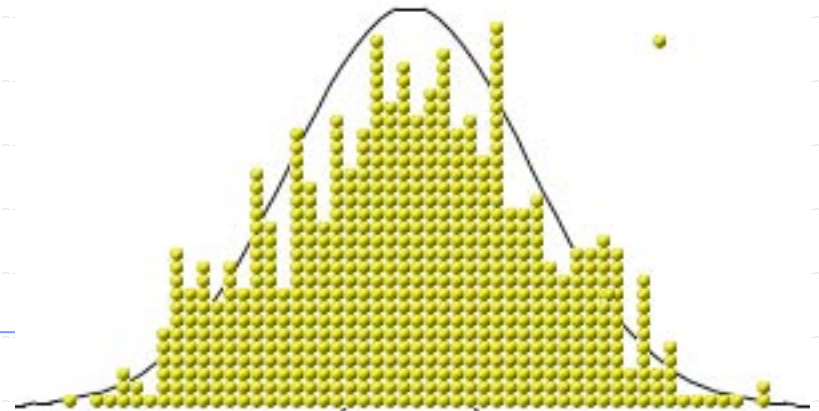
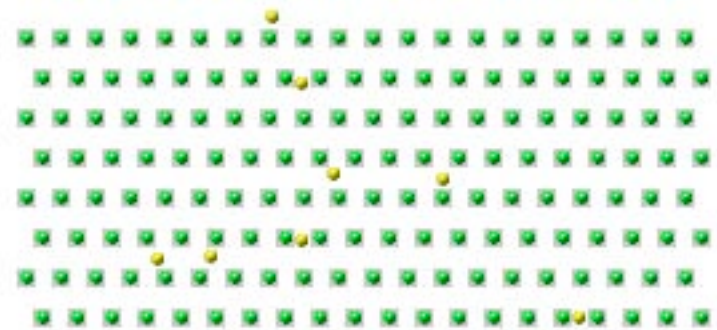
Lawrence Berkeley
National Laboratory

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California Energy Commission

Green Building Initiative Benchmarking Staff Workshop

April 7, 2005

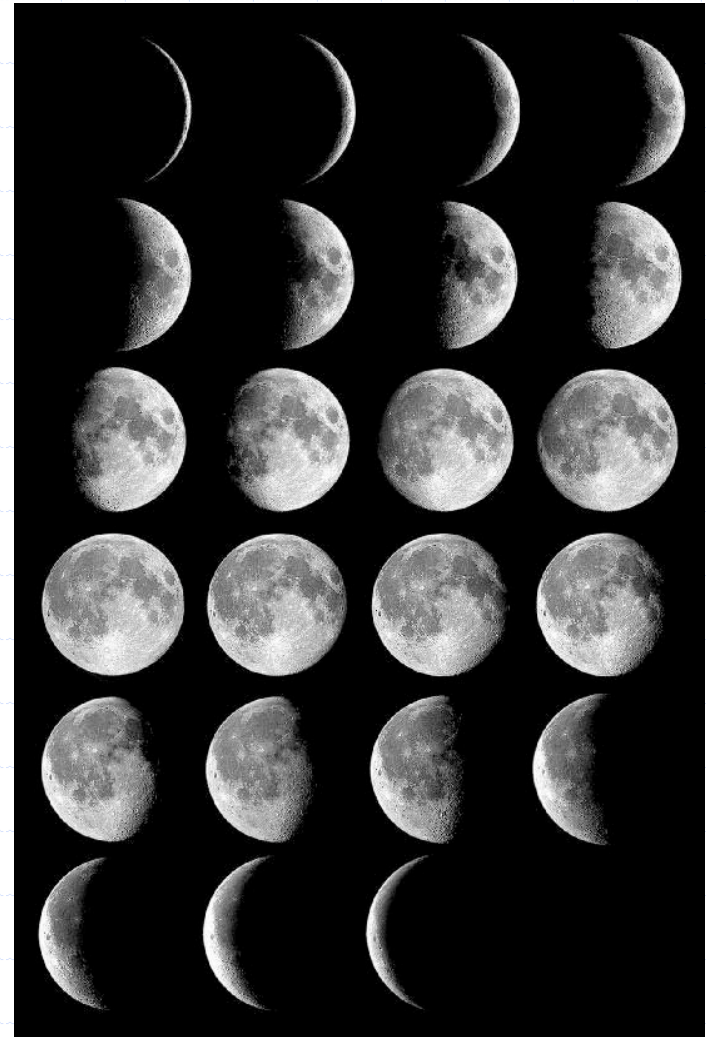
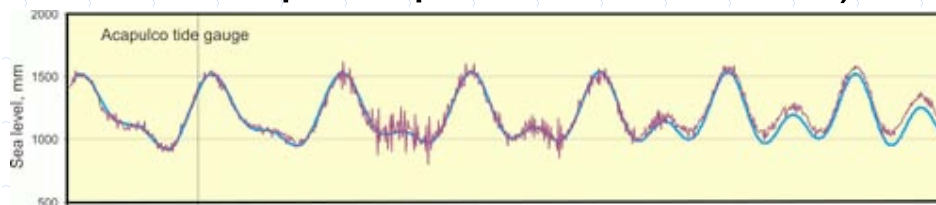


Describing complex systems; Informing action

....e.g., the moon's effect on earth



Tides in Acapulco (tsunami 12/26/2004
in red, superimposed on normals)



Origins: Sea-level observation ("bench" is old word for shore)

Tasmanian coastal
Benchmark c.1841

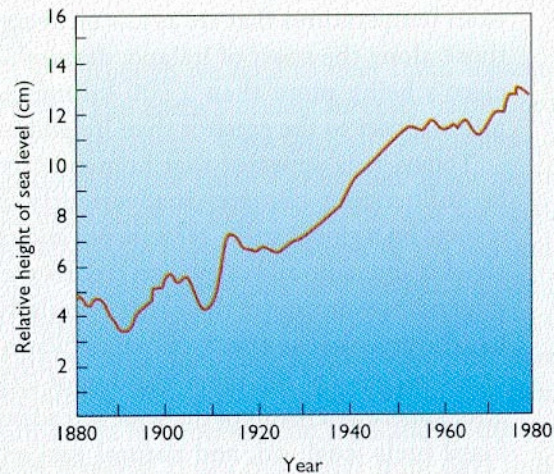
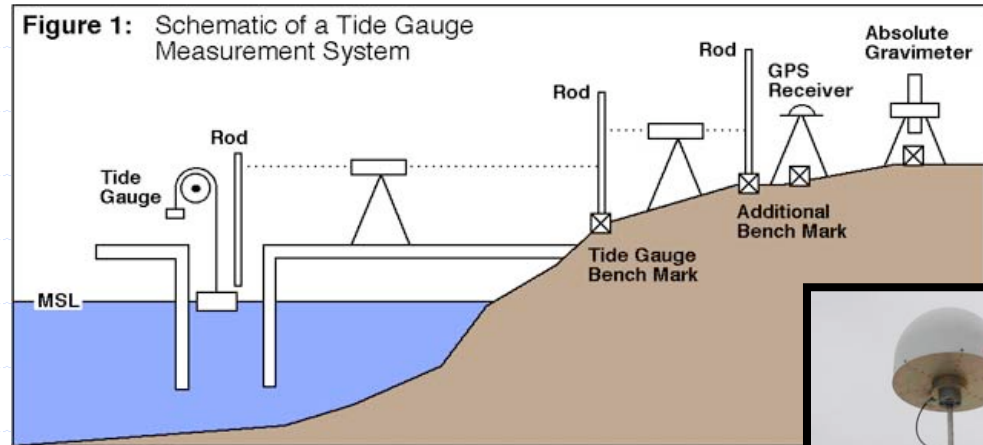
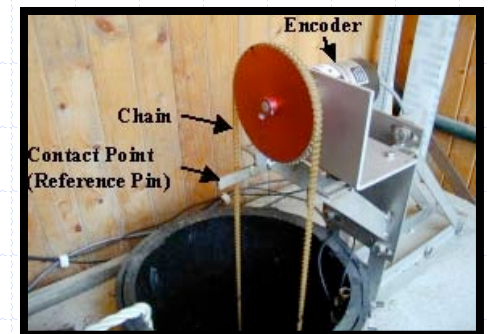
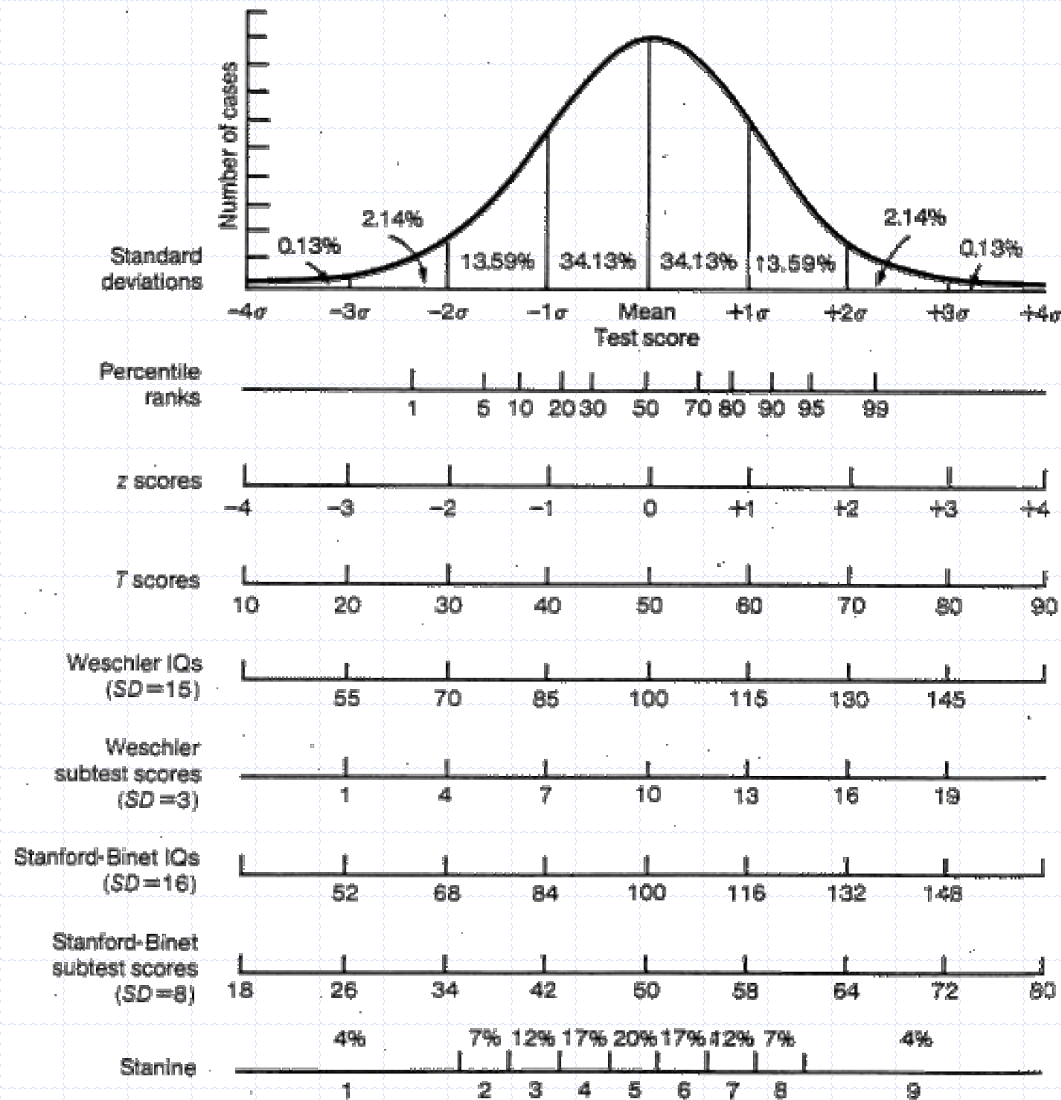


FIGURE 15-19

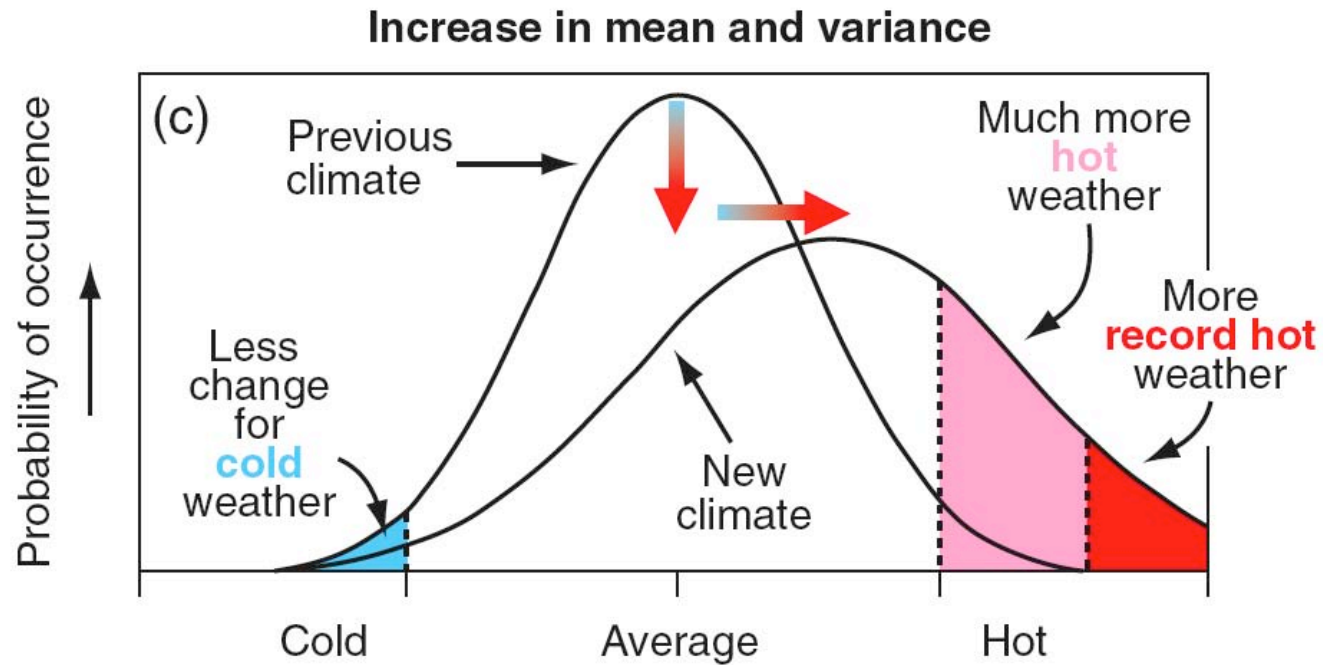
Sea levels. The recent global rise of sea level. [Adapted from V. Gornits, S. Lebedeff, and J. Hausen, *Science* 215 (1982): 1611-14.]



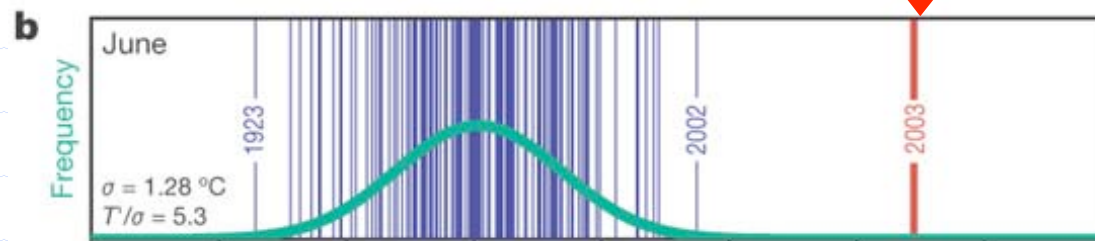
Familiar Benchmarks: IQ



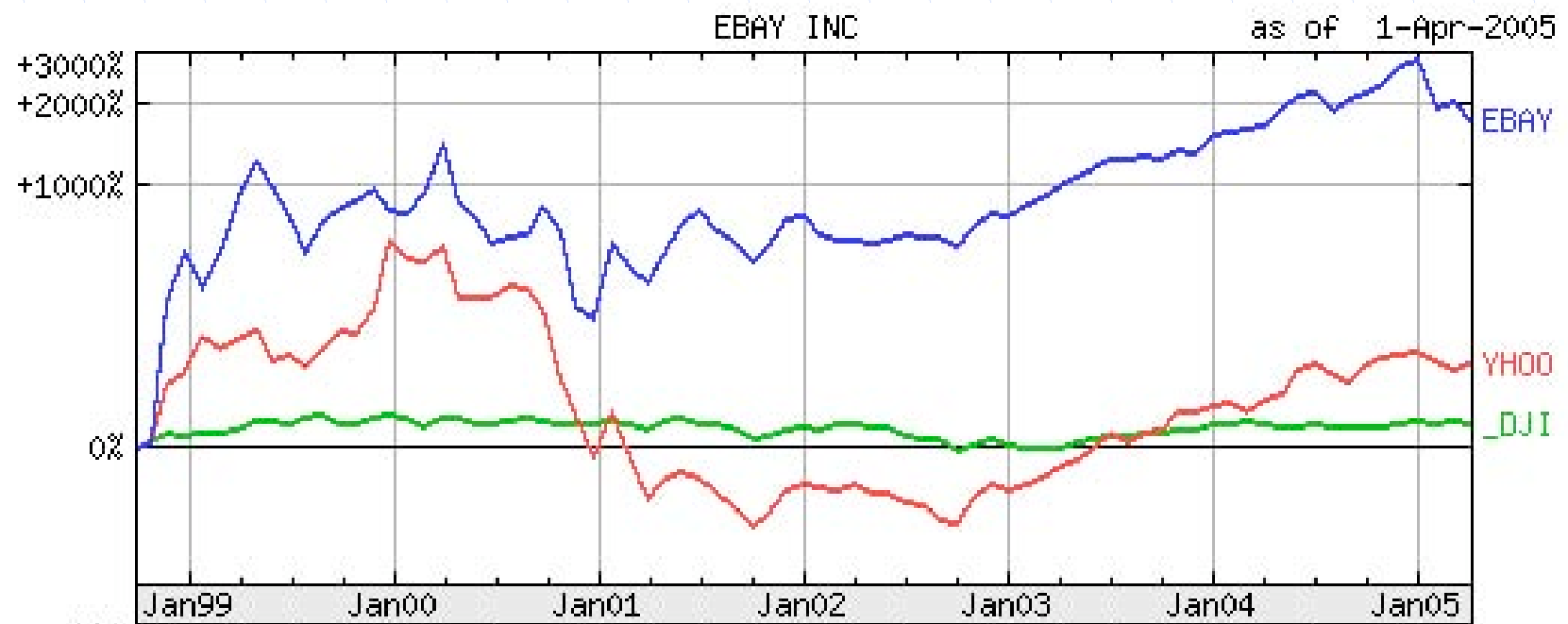
Climate Change



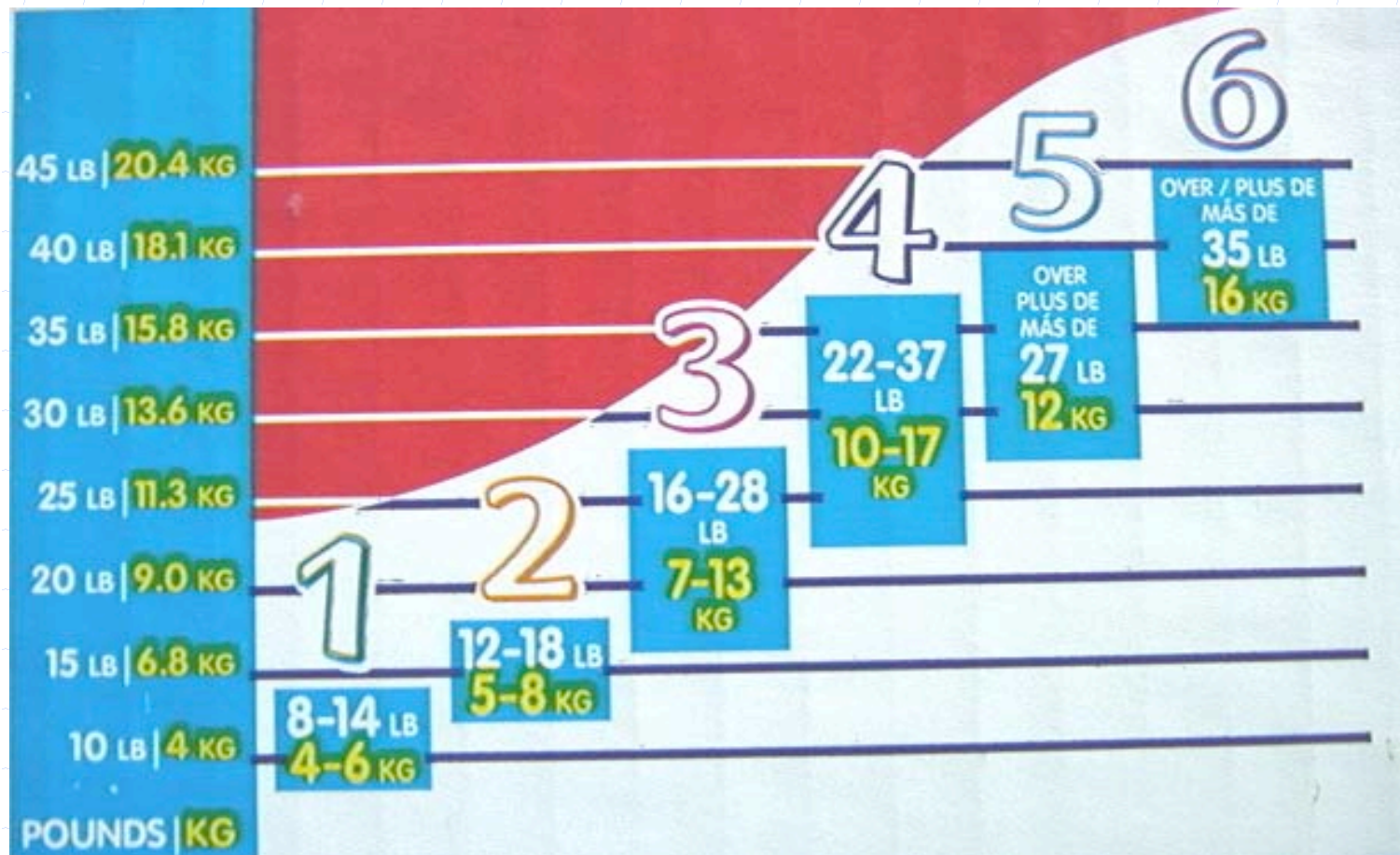
Europe Summer Temperatures: 2003



Benchmarks are Everywhere



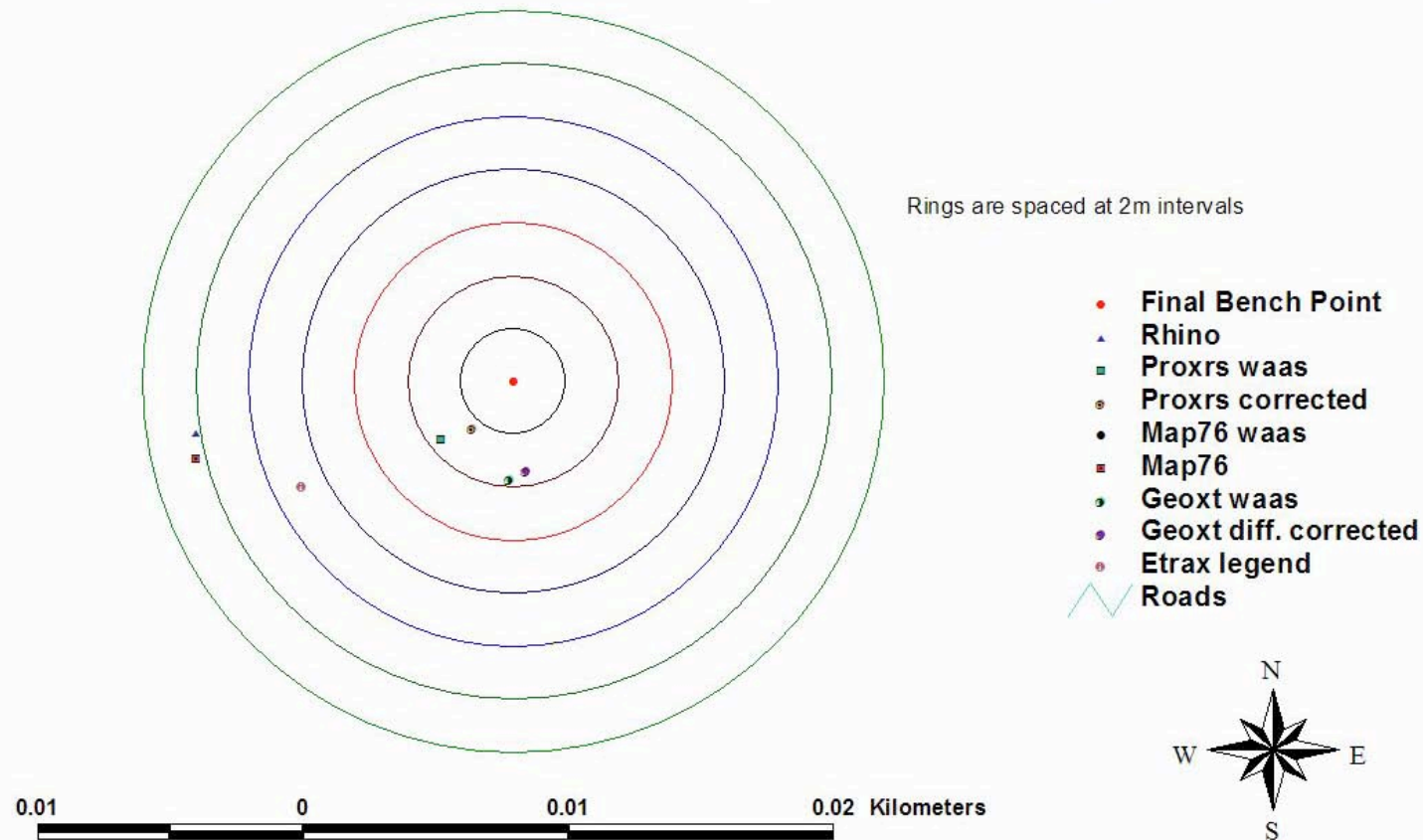
Huggies: Diaper Size as Function of Child Weight



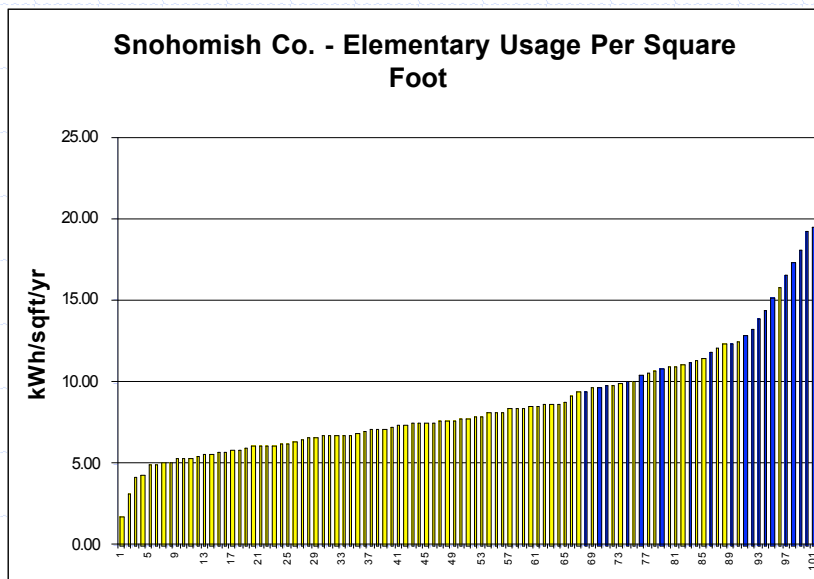
Nice chart; dubious value in real world
(parents don't pick diapers based on child's weight)

Bullseye

GPS Accuracy Comparisons



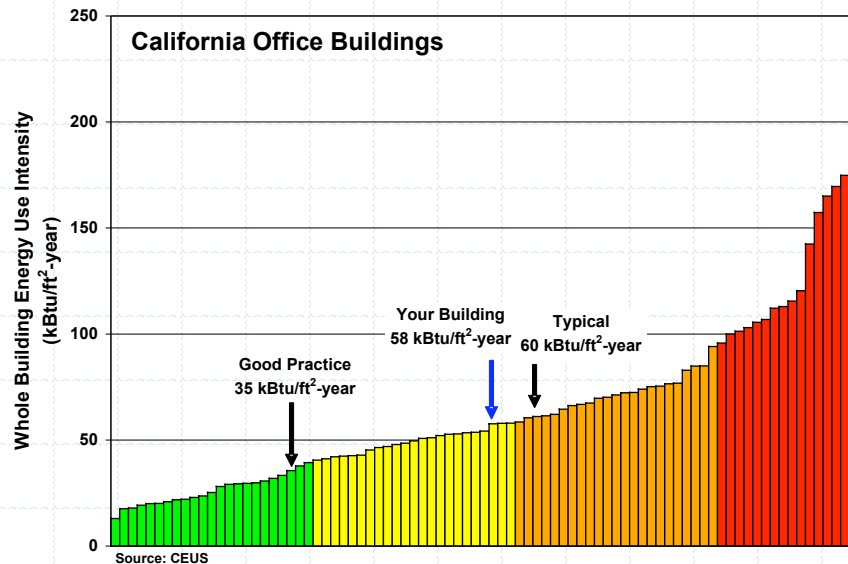
Why Benchmark Energy Use?



- ◆ Establish baseline and track performance
- ◆ Validate design
- ◆ Identify best practices; set goals or standards
- ◆ Identify savings potential
- ◆ Prioritize efforts
- ◆ Identify maintenance and control problems
- ◆ Educate; Inspire!

Energy benchmarking is one part of a broader energy management process

Many possible metrics



- ◆ Energy
 - ▼ (e.g. kBtu/ft²-degree day)
- ◆ Single fuel
- ◆ Peak power
- ◆ Cost
- ◆ Emissions
- ◆ “Unit-less” point systems
- ◆ Service level

Many approaches

- ◆ Statistical (bell curve; vs. population)
- ◆ Point-estimates (vs. population avg.)
- ◆ Point-based (vs. best practice)
- ◆ Model-based (actual vs. efficient)
- ◆ Standardized (vs. test procedure)

Scope: self-referential; enterprise; stock;
relationship to codes

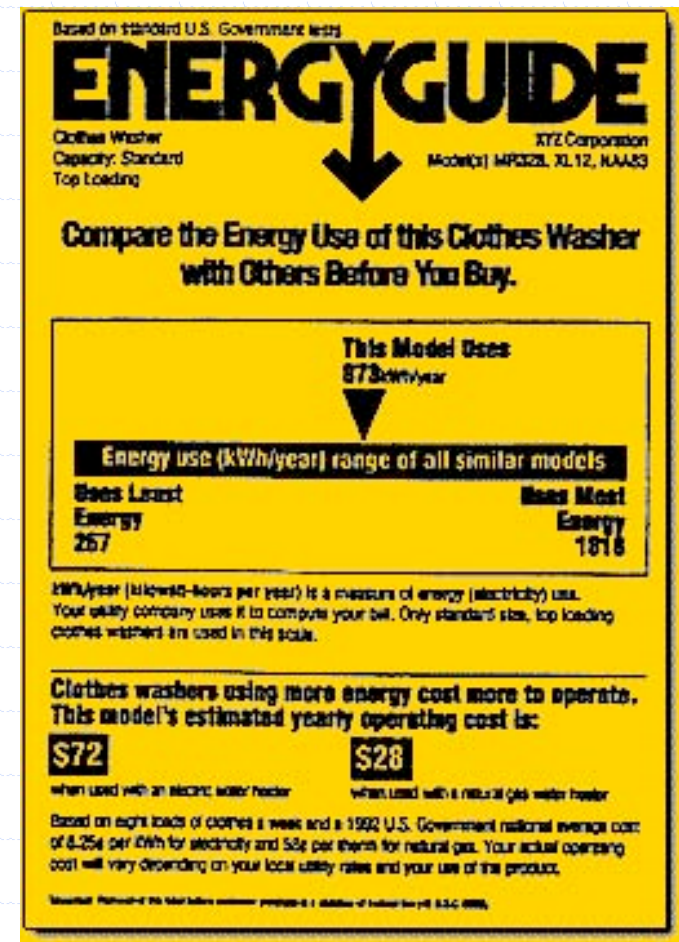
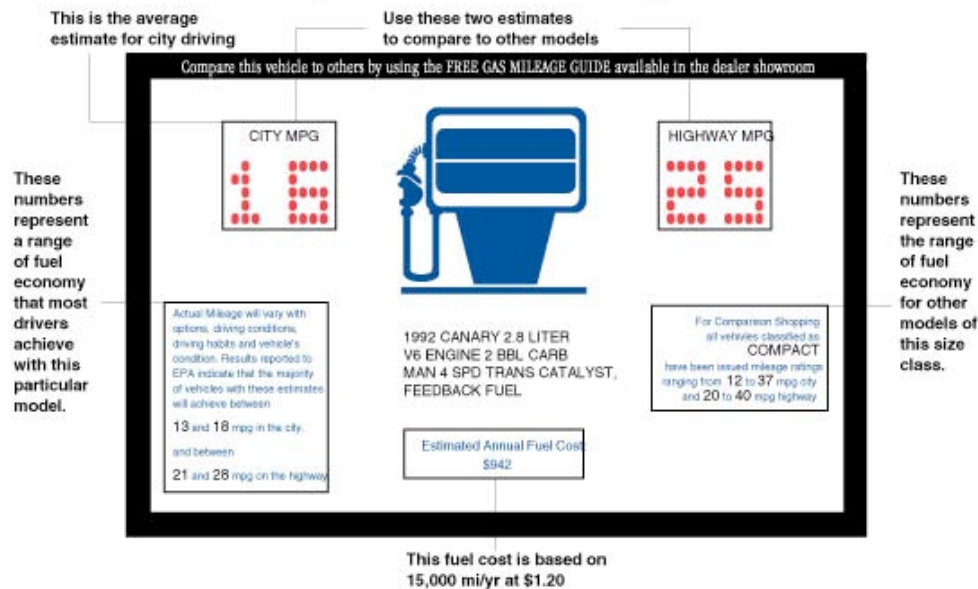
Timeframe: historic trends vs. current

Familiar Energy Benchmarks ...

...Fundamental differences in approach

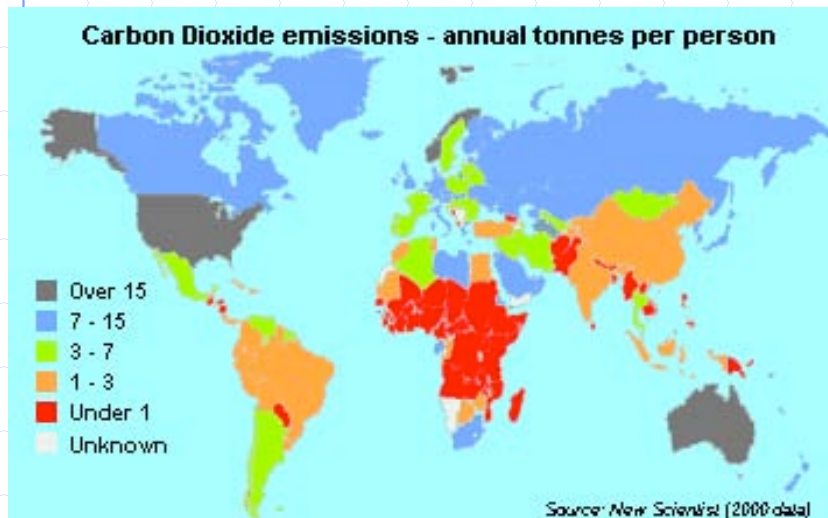


Sample Fuel Economy Label
(Attached to New Vehicle Window)



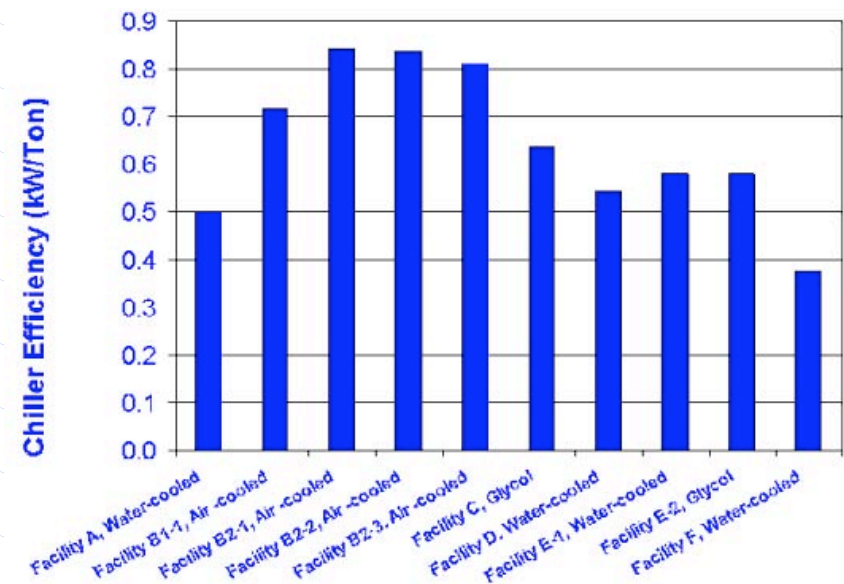
Benchmarking Can Be Done at Any Scale

- Global CO₂/Capita

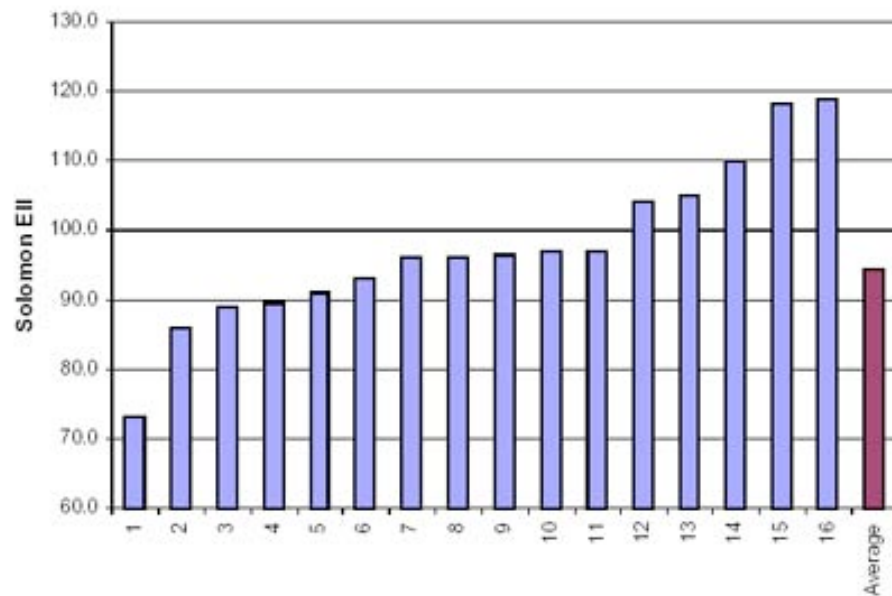


- Chiller efficiency

Chiller
efficiency



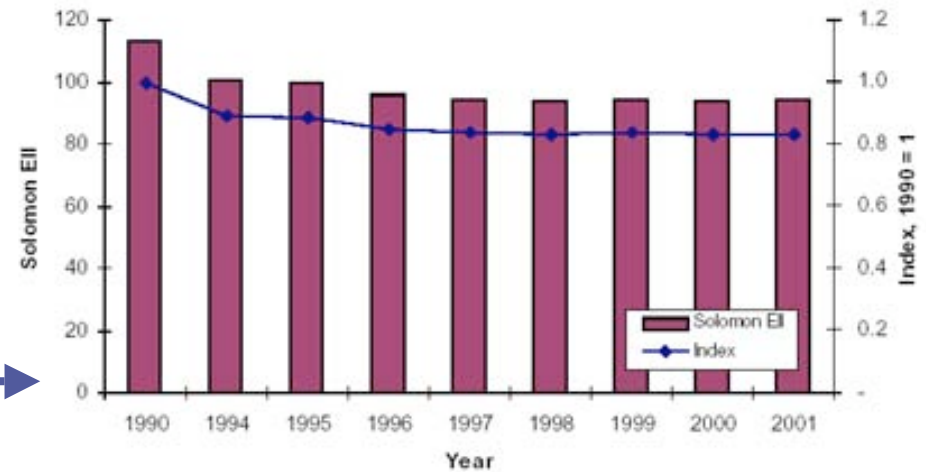
Lateral vs. Longitudinal: e.g. Oil Refineries



Solomon Energy Intensity Index of Participating Individual Refin
Source: CIEEDAC, 2002.

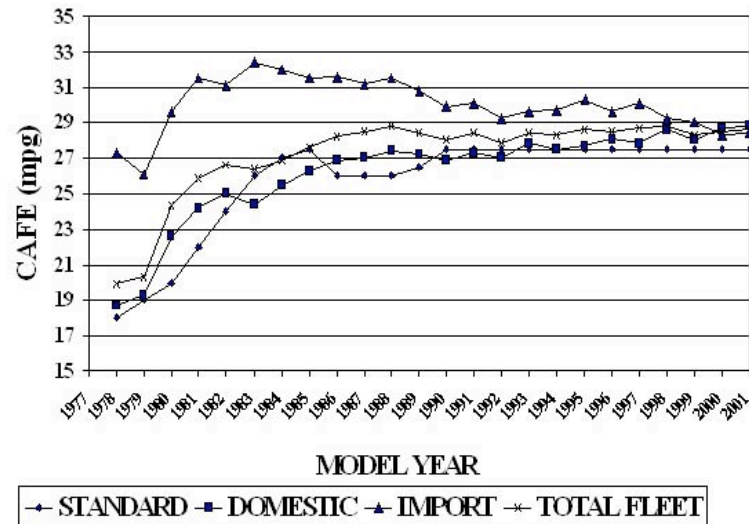
Comparing “peers” at
one point in time

Following “fleet-wide”
trends over time



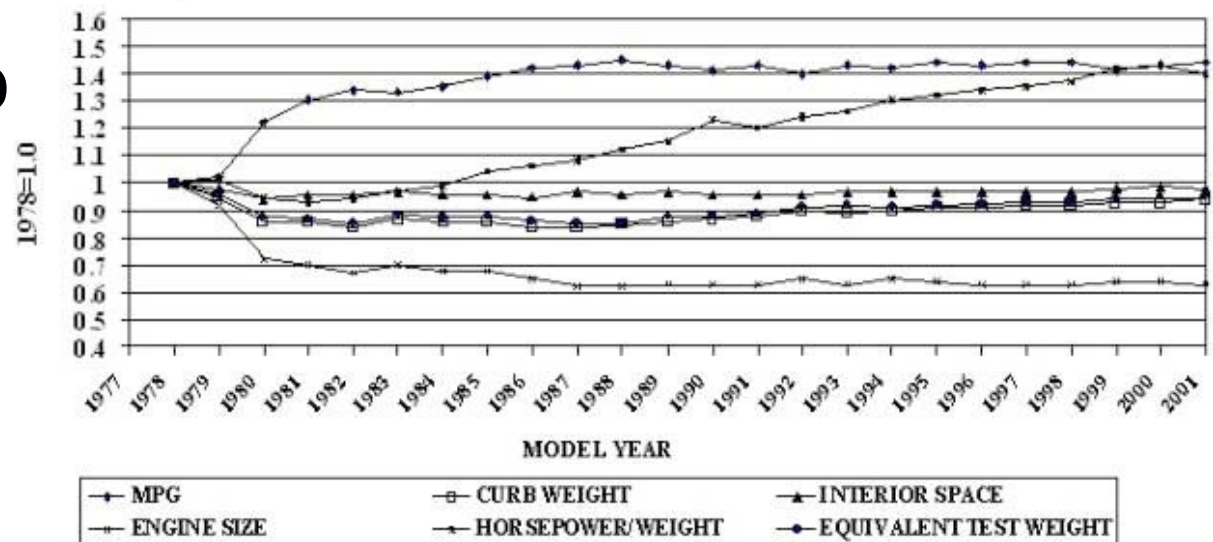
Average Refinery Energy Intensity based on a composite of Solomon EII for
all known refineries.⁴

Decide What is Important Before Benchmarking



◆ Important to isolate sub-groups of interest

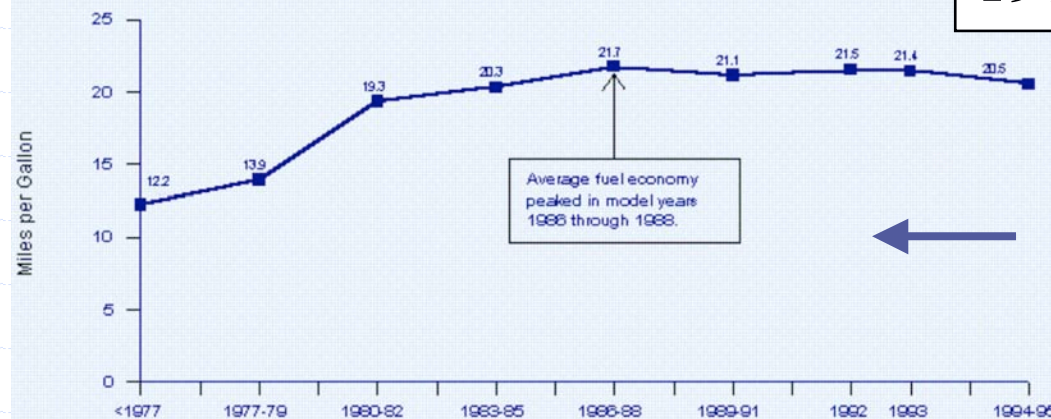
◆ Many ways to benchmark a given system



Source: NHTSA

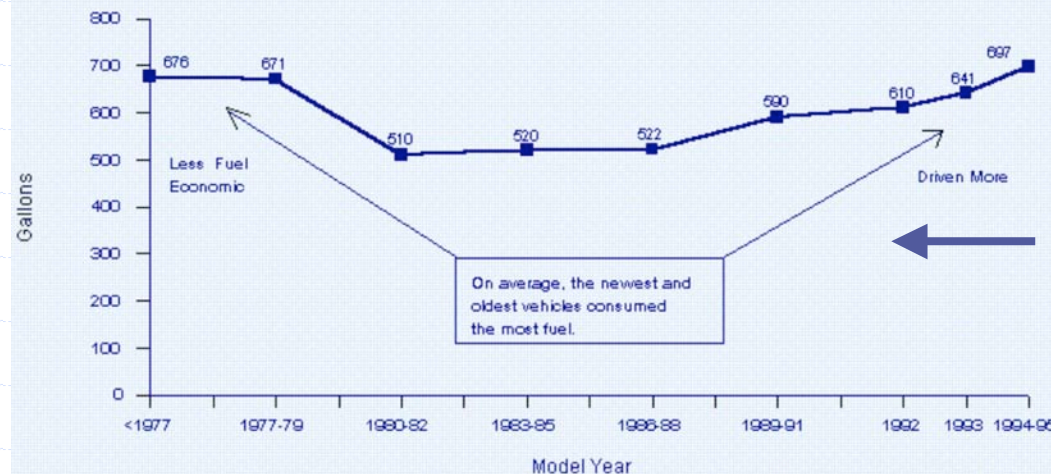
Choice of Benchmark Determines Conclusion

Figure 4.1 Average Fuel Economy of Residential Vehicles for Model Years Through 1995



Average US fuel economy increasing, then flat

Figure 4.9 Average Residential Vehicle Fuel Consumption per Vehicle for Model Years Through 1995



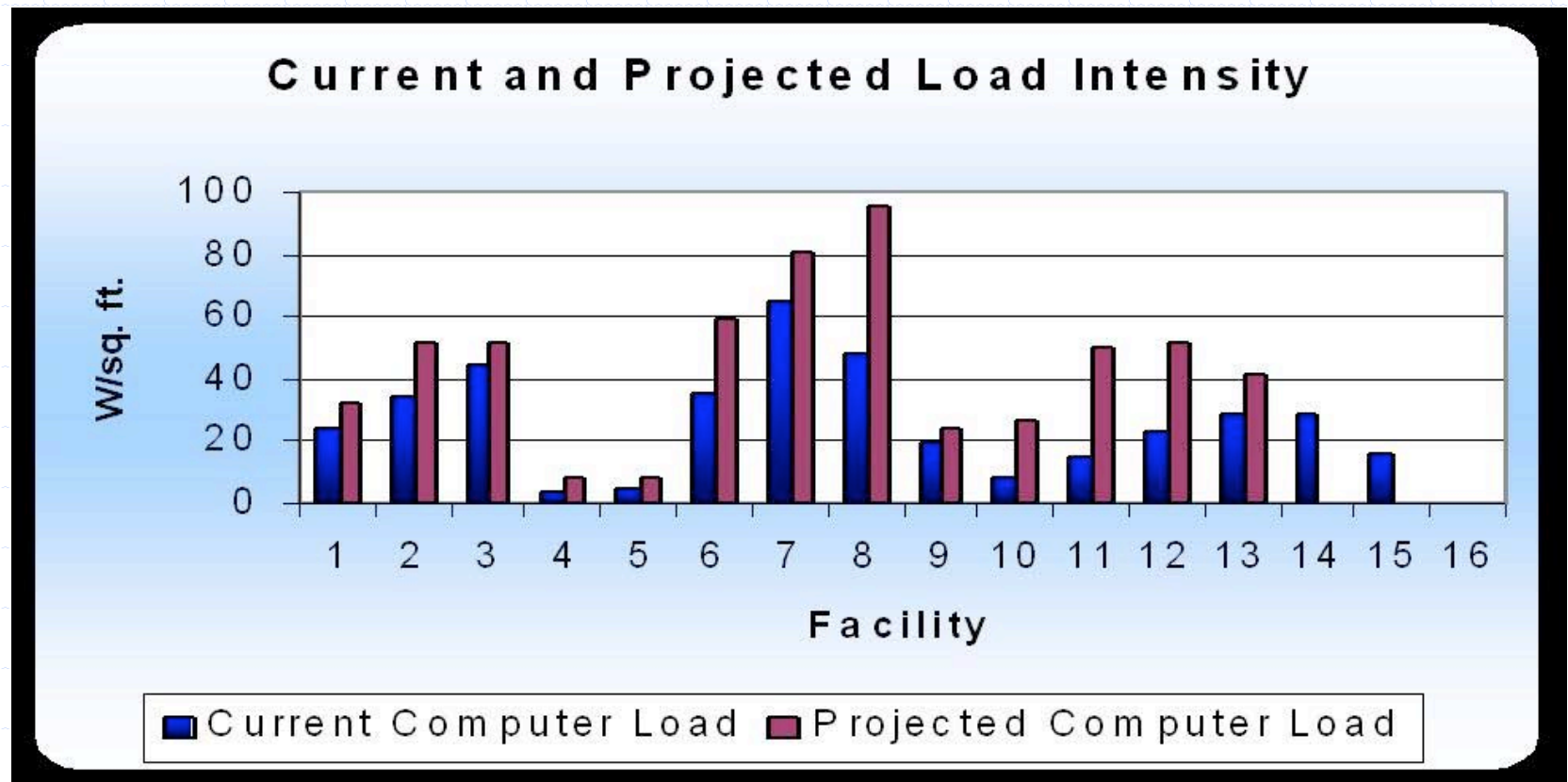
Average US vehicle fuel use declining, then rising

Source: USDOE/EIA

Benchmarks Can Provide a “Reality Check” for planners

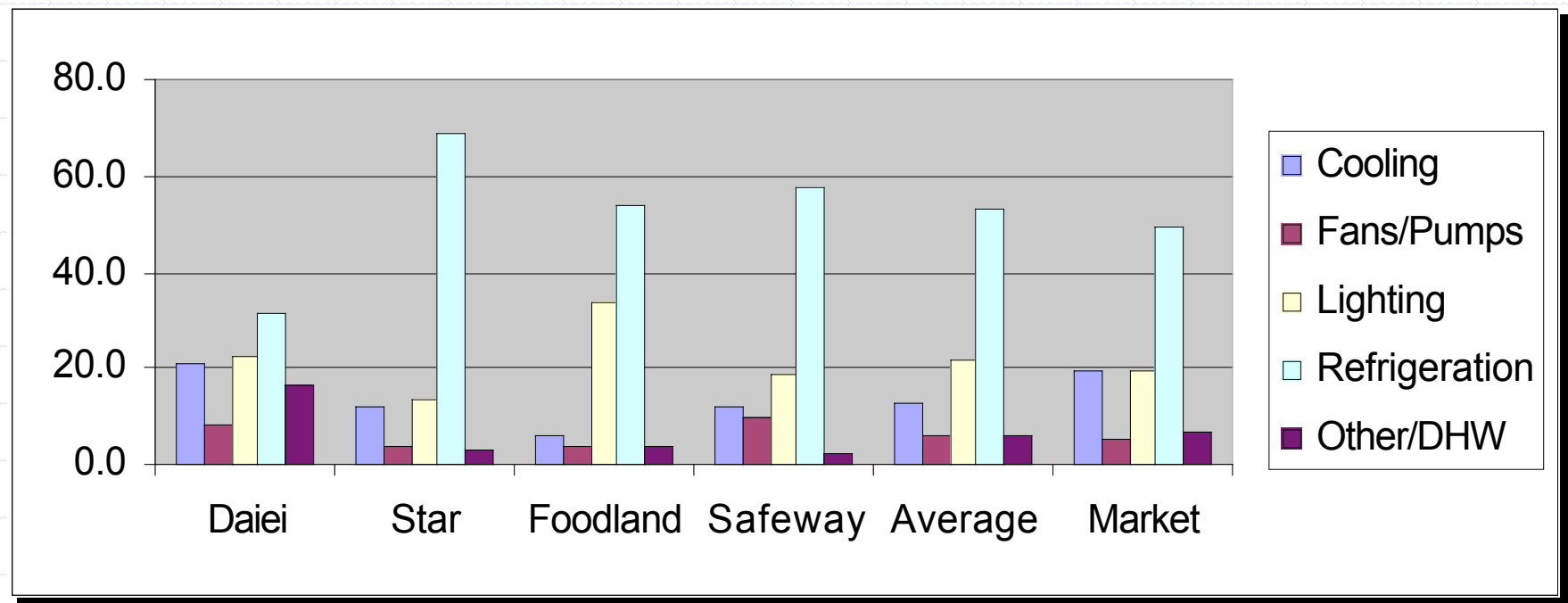
California Data Center owners claim a need of 250 W/ft²

Real data benchmarks the actual need between 10 and 100.



End-Use Intensities

Hawaiian Grocery Stores (kWh/ft²-year)



Source: HECO, Thomas D. Van Liew

Intensities x Enterprise

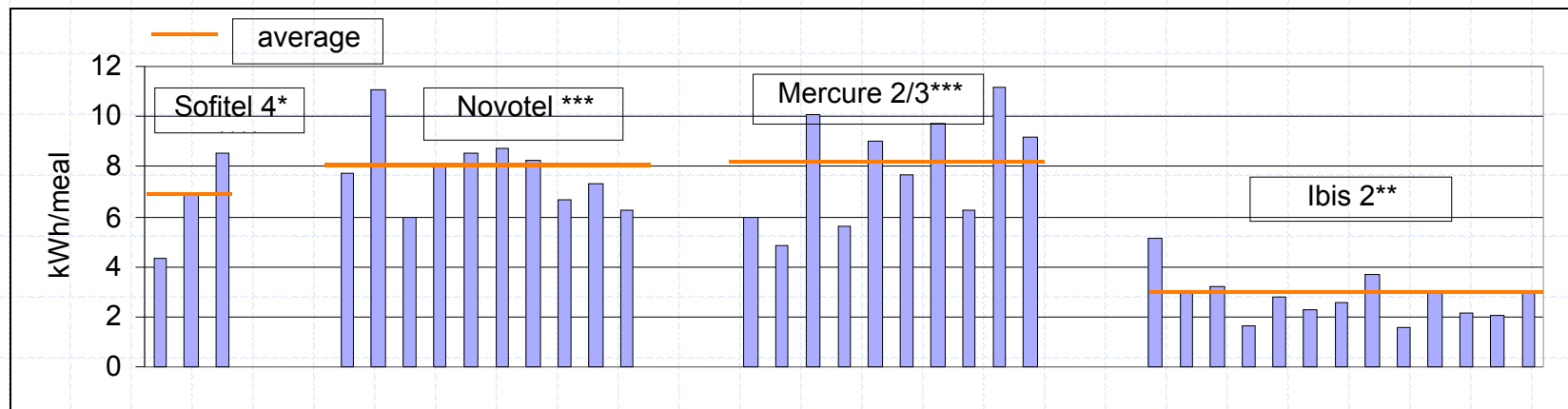
Energy per meal for 36 hotels, France

Std. Dev. 34%

27%

19%

32%



| category of hotels | conservation kWh/meal | cooking kWh/meal | dishwashing kWh/meal | total kWh/meal | standard deviation |
|--------------------|-----------------------|------------------|----------------------|----------------|--------------------|
| 2** | 0.44 | 2.08 | 0.25 | 2.77 | 0.94 |
| 2**/3*** | 3.81 | 3.89 | 0.25 | 7.95 | 2.18 |
| 3*** | 3.67 | 3.99 | 0.21 | 7.86 | 1.47 |
| 4**** | 2.53 | 3.92 | 0.13 | 6.58 | 2.13 |

Source: Le Strat et al., (1999)

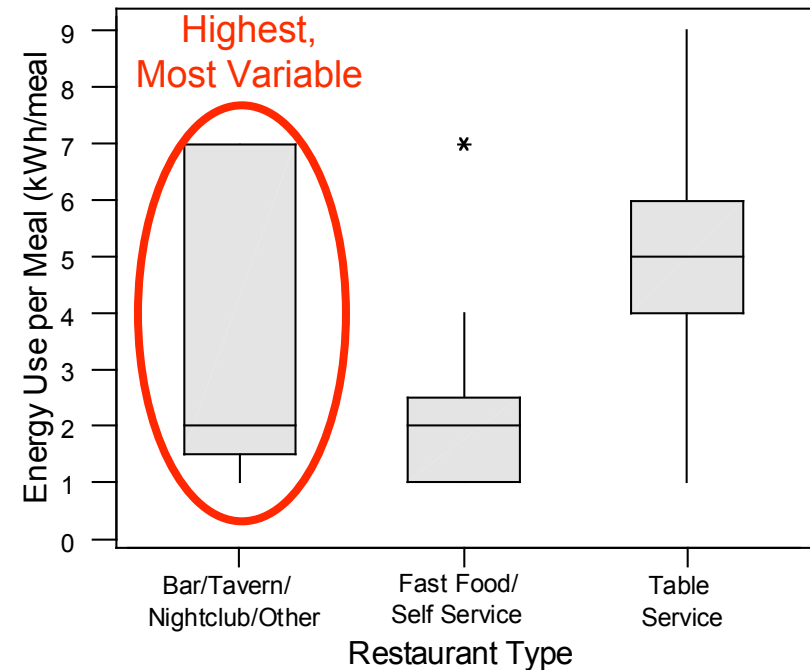
Choice of Indicator is Key

Restaurants

Energy per unit floor area



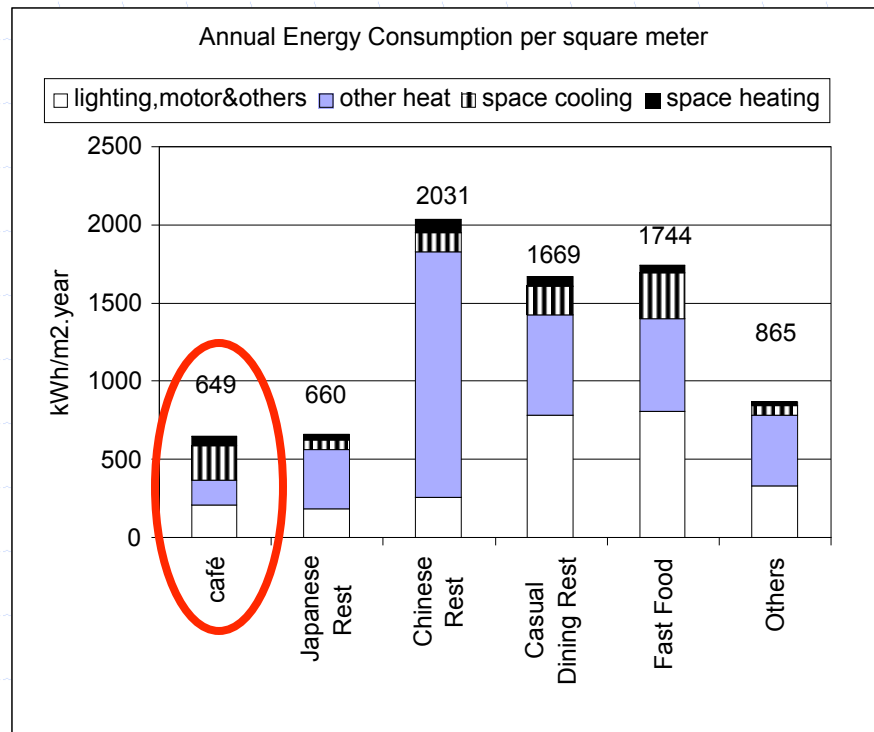
Energy per meal



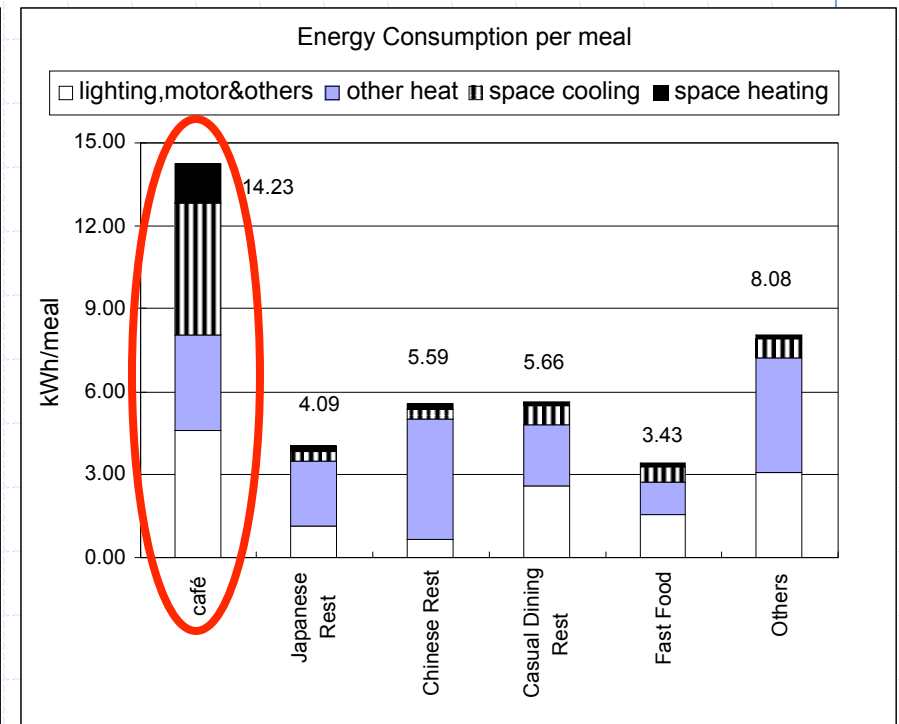
Source: 1996 California Commercial End Use Survey

Choice of Indicator is Key

Energy per unit floor area



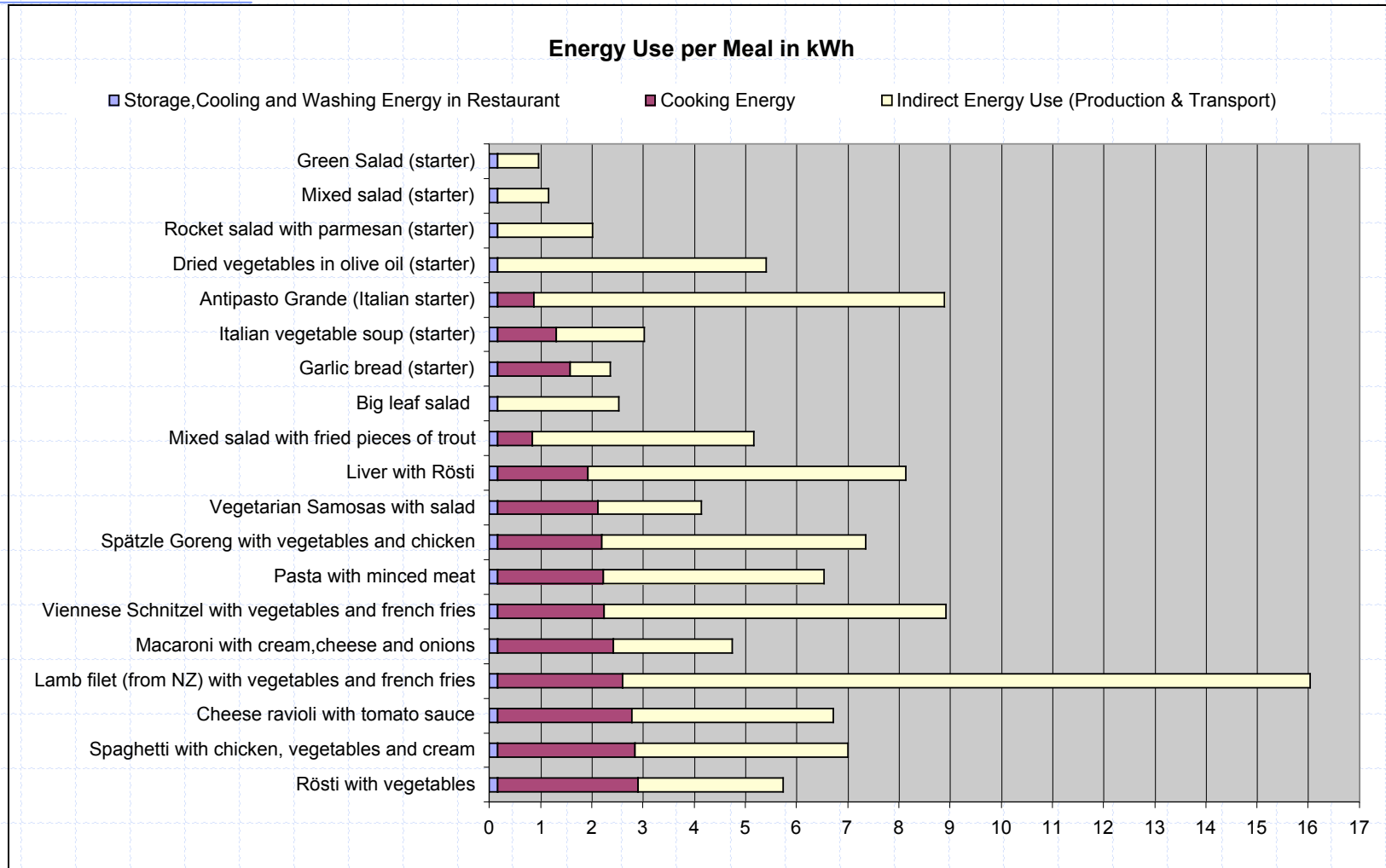
Energy per meal



Café ranks “best” by one benchmark and “worst” by the other

Source: The Energy Data and Modeling Center, 2001

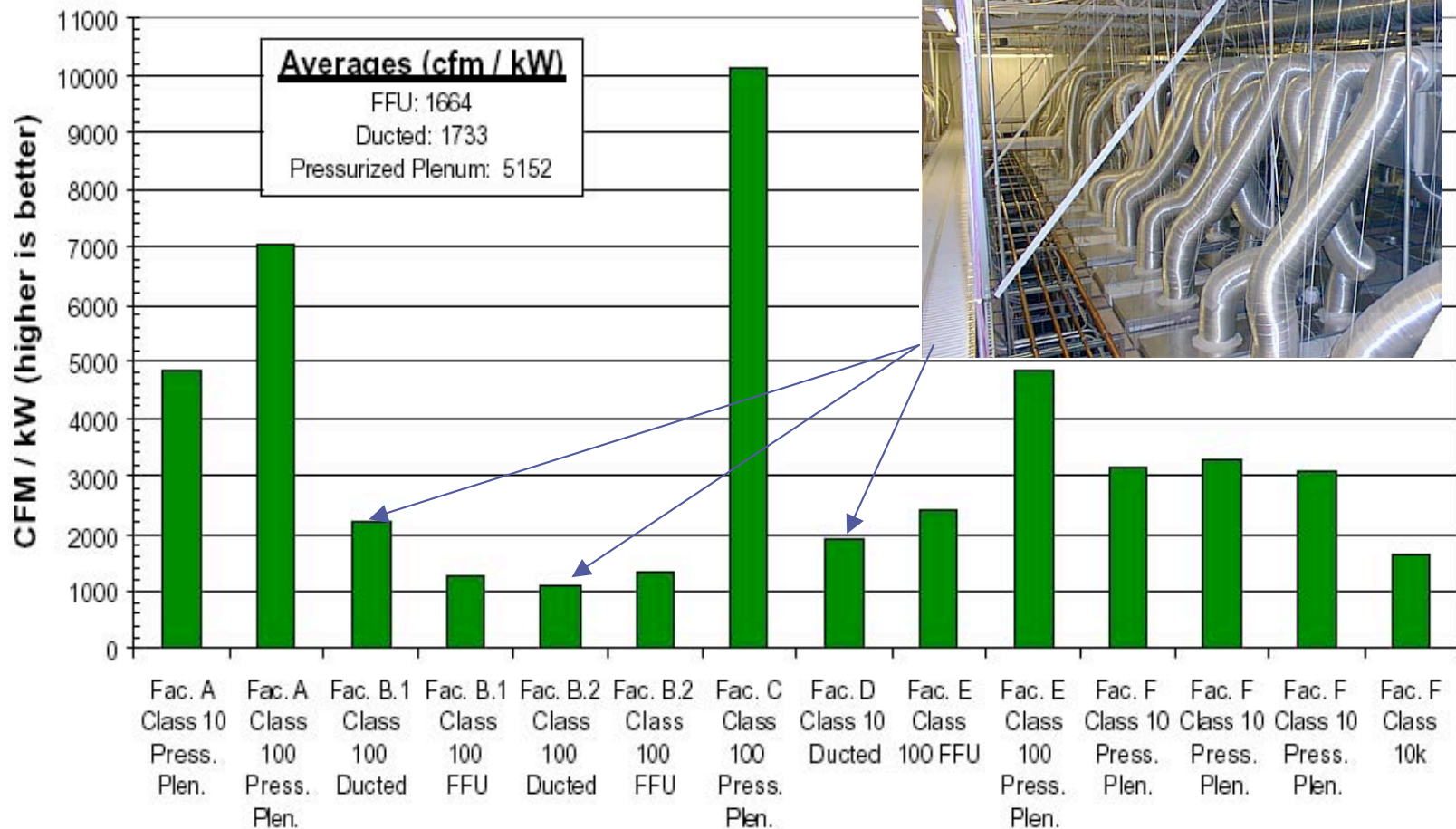
Beyond “Apples & Oranges”: Pippins and Granny Smiths



Data for Switzerland. Source: Balmer and Hintermann, 2000

Delivery of Service Levels: Cleanrooms

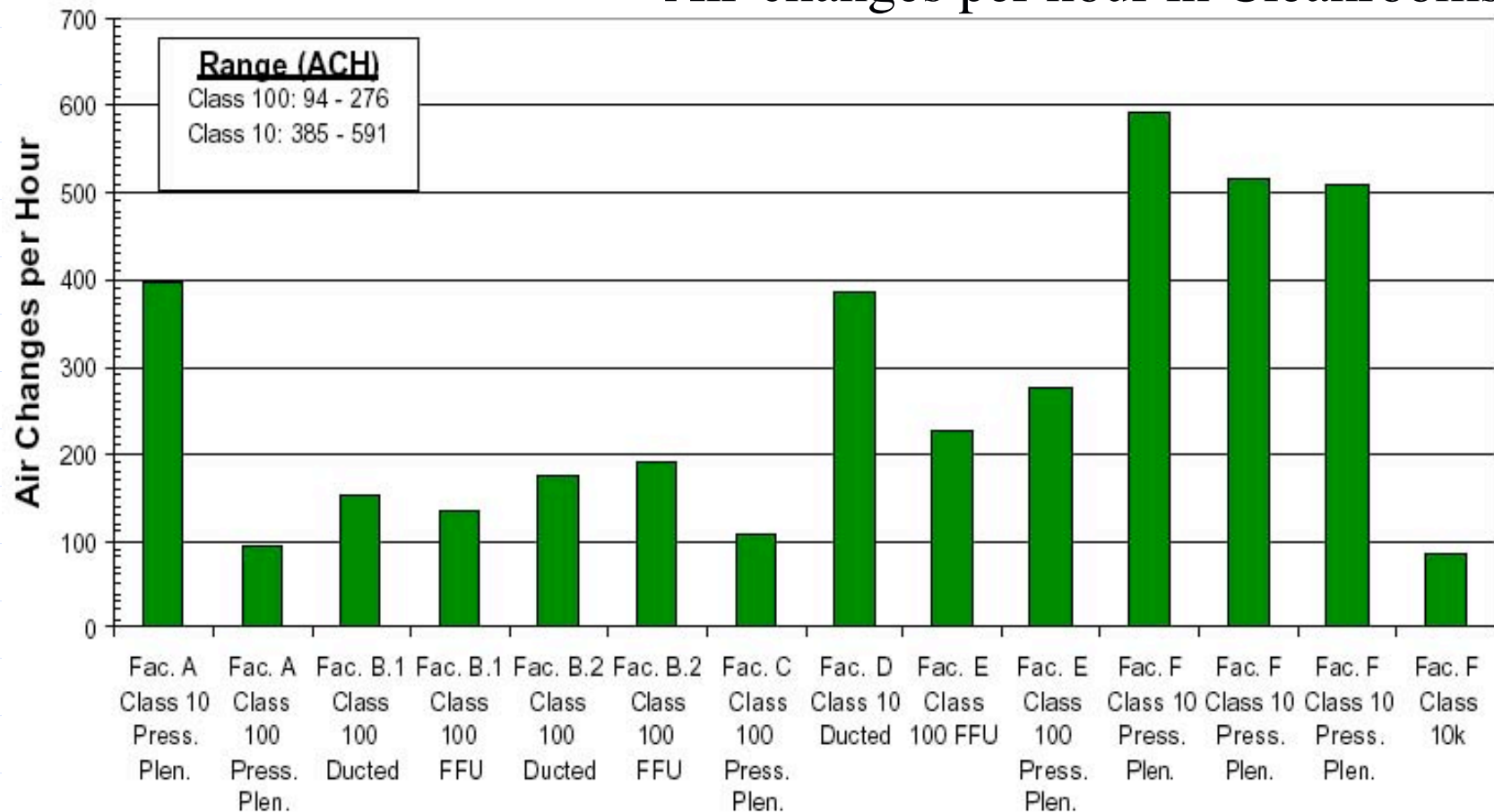
Air movement CFM/kW (higher is better)



Tschudi and Xu, *ASHRAE Transactions*, KC-03-9-4 (2003)

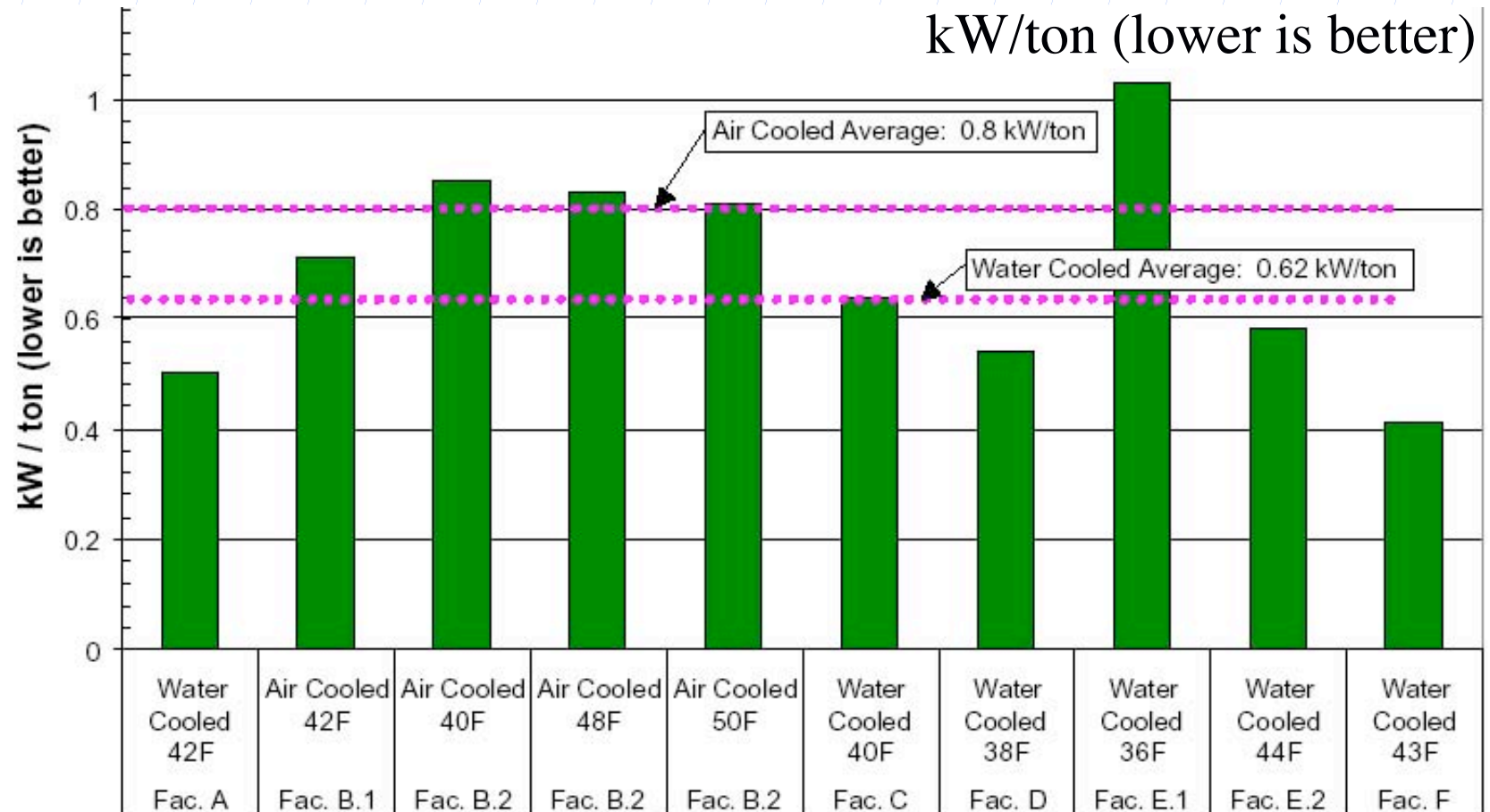
Some “Energy” Benchmarks Don’t Even Include Energy

Air-changes per hour in Cleanrooms



Tschudi and Xu, *ASHRAE Transactions*, KC-03-9-4 (2003)

Component Benchmarking: Cleanroom Chiller Efficiencies



Tschudi and Xu, *ASHRAE Transactions*, KC-03-9-4 (2003)

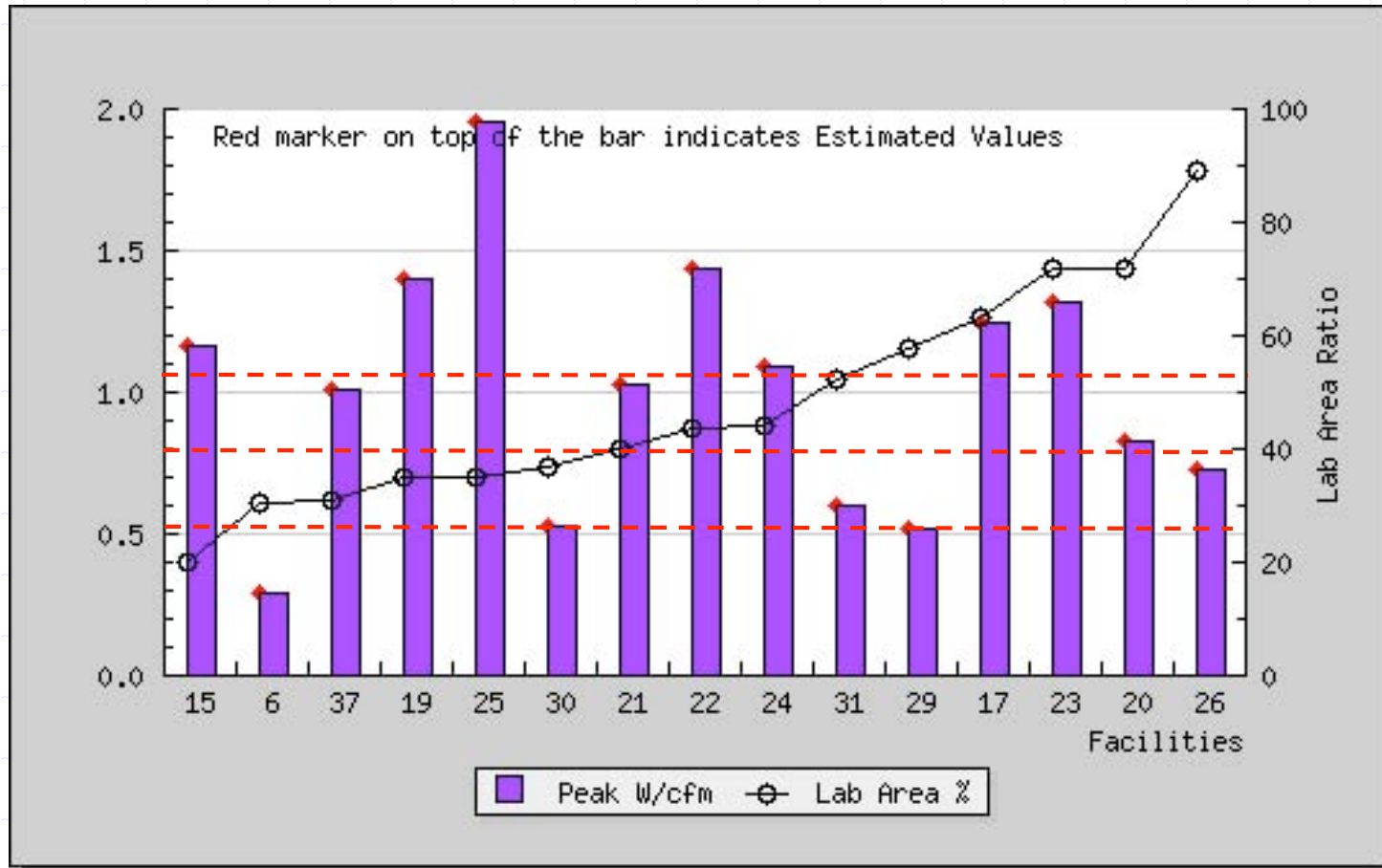
Cleanroom Energy Metrics

| | |
|---|-----------------------------|
| •Recirculation air handler efficiency | •cfm/kW |
| •Makeup air handler efficiency | •cfm/kW |
| •Annual energy cost per cleanroom square foot | •\$/ft ² |
| •Annual fuel usage | •MBtu/ft ² -yr |
| •Annual electricity usage | •kWh/ft ² -yr |
| •Annual energy usage | •MBtu/ft ² -yr |
| •Makeup air | •cfm/ft ² |
| •Recirculation air | •cfm/ft ² or ach |
| •Chiller efficiency | •kW/ton |
| •Tower efficiency | •kW/ton |
| •Condenser water pump efficiency | •kW/ton |
| •Chilled water pump efficiency | •kW/ton |
| •Total chilled-water plant efficiency | •kW/ton |
| •Hot water pumping efficiency | •kW/MBtu |
| •Cooling load density | •ft ² /ton |

Tschudi and Xu, *ASHRAE Transactions*, KC-03-9-4 (2003)

From Benchmarking to Best Practices

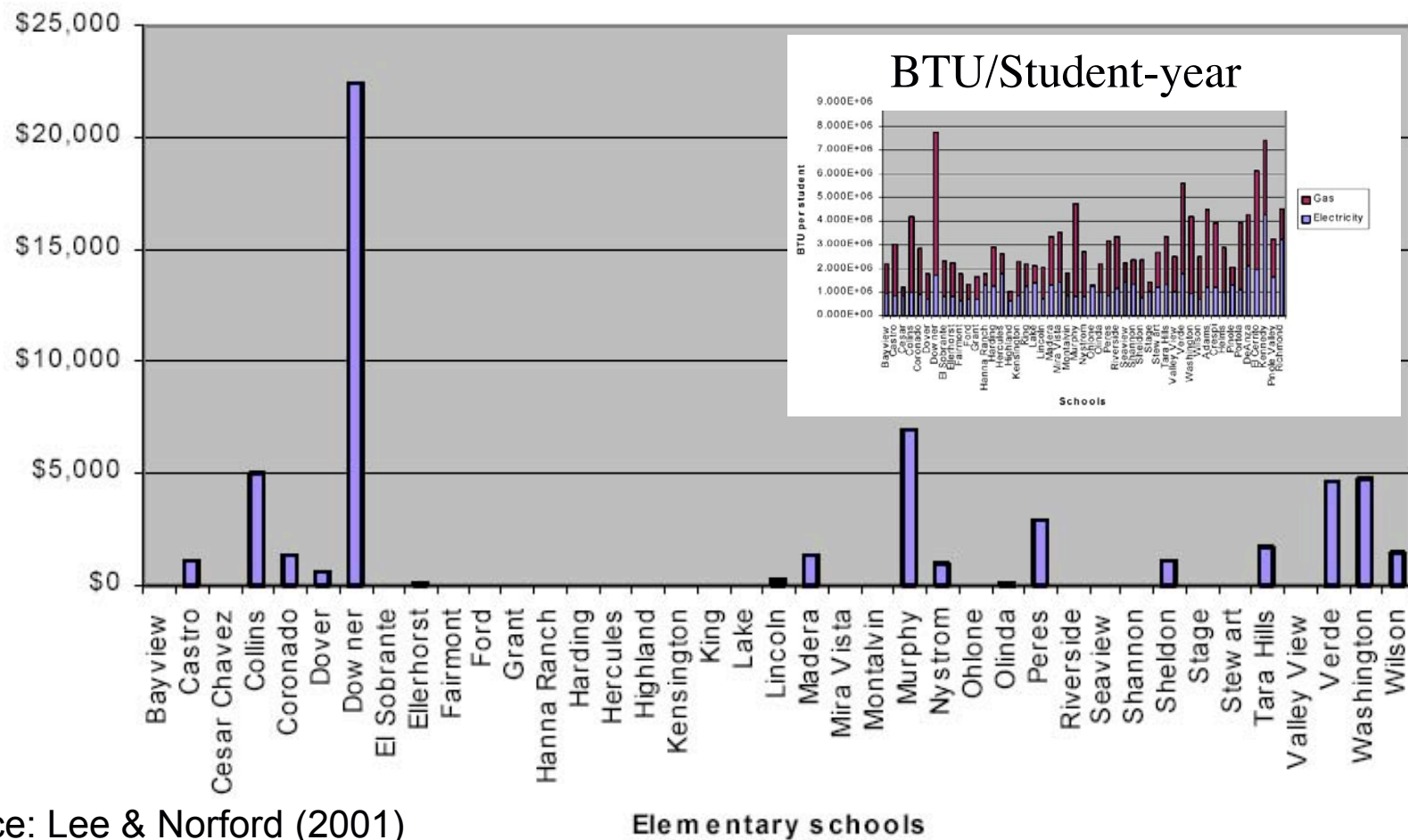
Laboratory Ventilation W/cfm



Standard, good, better benchmarks as defined in
"How-low Can You go: Low-Pressure Drop Laboratory Design"
by Dale Sartor and John Weale, ASHRAE Journal

Benchmarks as Screening Tool

Gas \$ Savings if Brought to Median Value



Source: Lee & Norford (2001)

Elementary schools

Labs21 Benchmarking Tool Analysis

Benchmarking Labs for the 21st Century Web Toolkit - Microsoft Internet Explorer

Address: http://www.dc.lbl.gov/Labs21/CompareData.php?UserID=2

LABS FOR THE 21ST CENTURY

benchmarking

Choose Metrics and Filtering Criteria

[More Information](#)

User: **LBNL**
Organization: **Lawrence Berkeley National Laboratory**

Please specify the metric criteria -

System: Total Building
Energy / Efficiency Metric: BTU/sf-yr (site)

Please specify the filtering criteria -

1. Lab Area / Gross Area ratio
is greater than or equal to 0.00 and is less than or equal to 0.99

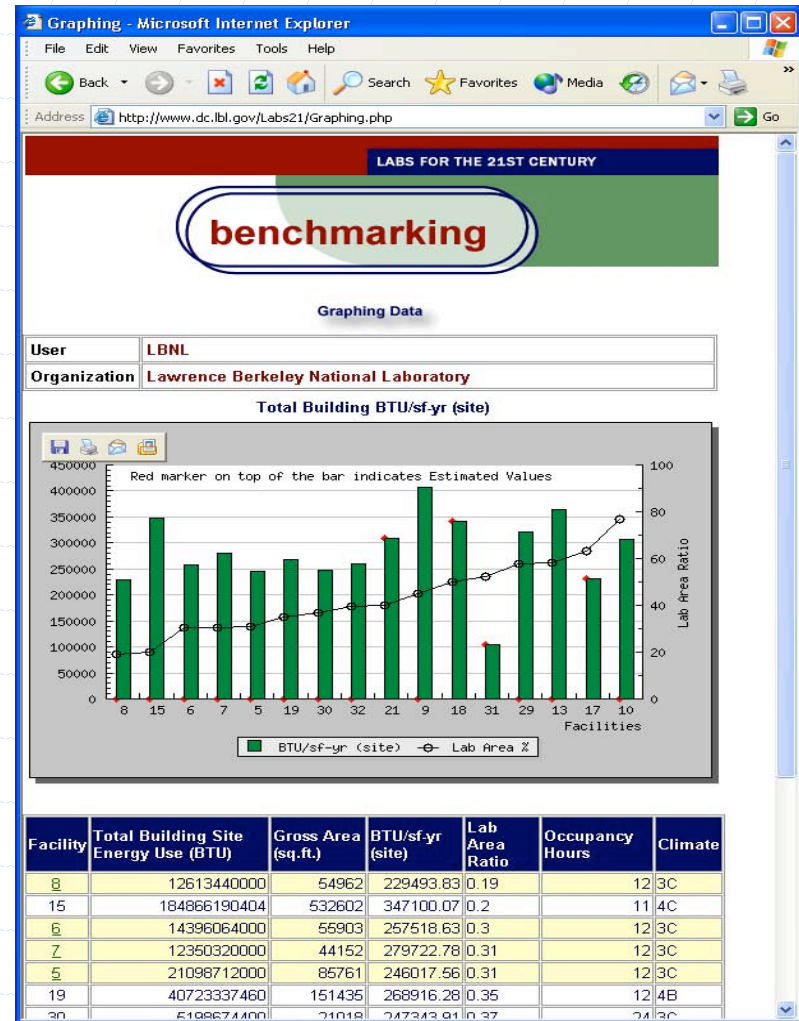
2. Occupancy
☐ Standard (≤ 14 hours)
☐ High (> 14 hours)
☒ Both (all data)

3. Climate [Climate Code, Climate Type, Representative City]
(To view the map of climatic distribution)

☒ 1A, **Very Hot - Humid** (Miami, FL)
☒ 2B, **Hot - Dry** (Phoenix, AZ)
☒ 3B, **Warm - Dry** (El Paso, TX)
☒ 4A, **Mixed - Humid** (Baltimore, MD)
☒ 4C, **Mixed - Marine** (Salem, OR)
☒ 5B, **Cool - Dry** (Bosie, ID)
☒ 6B, **Cold - Dry** (Helena, MT)
☒ 8, **Subarctic** (Fairbanks, AK)

☒ 2A, **Hot - Humid** (Houston, TX)
☒ 3A, **Warm - Humid** (Memphis, TN)
☒ 3C, **Warm - Marine** (San Francisco, CA)
☒ 4B, **Mixed - Dry** (Albuquerque, NM)
☒ 5A, **Cool - Humid** (Chicago, IL)
☒ 6A, **Cold - Humid** (Burlington, VT)
☒ 7, **Very Cold** (Duluth, MN)

[Reset Values](#) [Continue...](#)



Capturing Benchmarks with Design Intent Documentation

Design Intent Tool 1.0 - [LBNL Project Template for Laboratories]

File

Introduction | Manage Project Files | Manage Template Files | User Guide | Feedback | Help | Web Home Page

Design Intent Document | Owner's Goals & Project Info | Team Contact Info | Reports

Design Intent Tool 1.0
Project Name: LBNL Project Template for Laboratories
Owner: LBNL
Today's Date: 08-20-2002

Select Design Area

+/- Add/Remove

☒ General
☐ Architectural: Loads
☐ Mechanical: Ventilation System
☐ Mechanical: Chiller Plant
☐ Mechanical: Heating Plant
☐ Electrical: Lighting System
☐ Electrical: Distribution System
☐ Electrical: Renewable/Distributed
☐ Process: Process/Plug Loads
☐ Operations and Maintenance

Design Area Description

This area includes whole-building information or information pertaining to multiple design areas.

Select Objective

+/- Details Click this button to add, remove or edit Objectives for this project

| Objective Name | Objective Description |
|--|--|
| Achieve high overall energy efficiency | Energy efficiency is low energy consumption to accomplish a given task. High overall efficiency is low whole-building energy use (electric energy, peak electric power demand, natural gas, and any other fuels) to provide a laboratory building of a certain |

Strategies

+/- Details Click this button to add, remove or edit Strategies for the Objective selected above.

| Index | Strategy Name | Strategy Description |
|-------|--|---|
| 1 | Exceed Title 24 requirement by factor of 2.5 (energy use 40% of Title 24 budget) | Energy code requirements can typically be easily outperformed. Such requirements make a convenient baseline against which simulated performance can be compared. Title 24 is California's State Energy Code. Buildings can comply with the Code either by the prescriptive or |
| 2 | Achieve LEED Platinum rating | The Leadership in Energy and Environmental Design (LEED) system was created by the U.S. Green Building Council to comprehensively rate buildings for their environmental impact and sustainability. Platinum is the highest rating. |
| 3 | Minimize life-cycle cost | The life-cycle cost of a building is its total cost over its entire life, including design, construction, operation, maintenance, renovation, and decommissioning; future costs are discounted to present value for comparison. Minimizing life-cycle costs usually results in higher first |

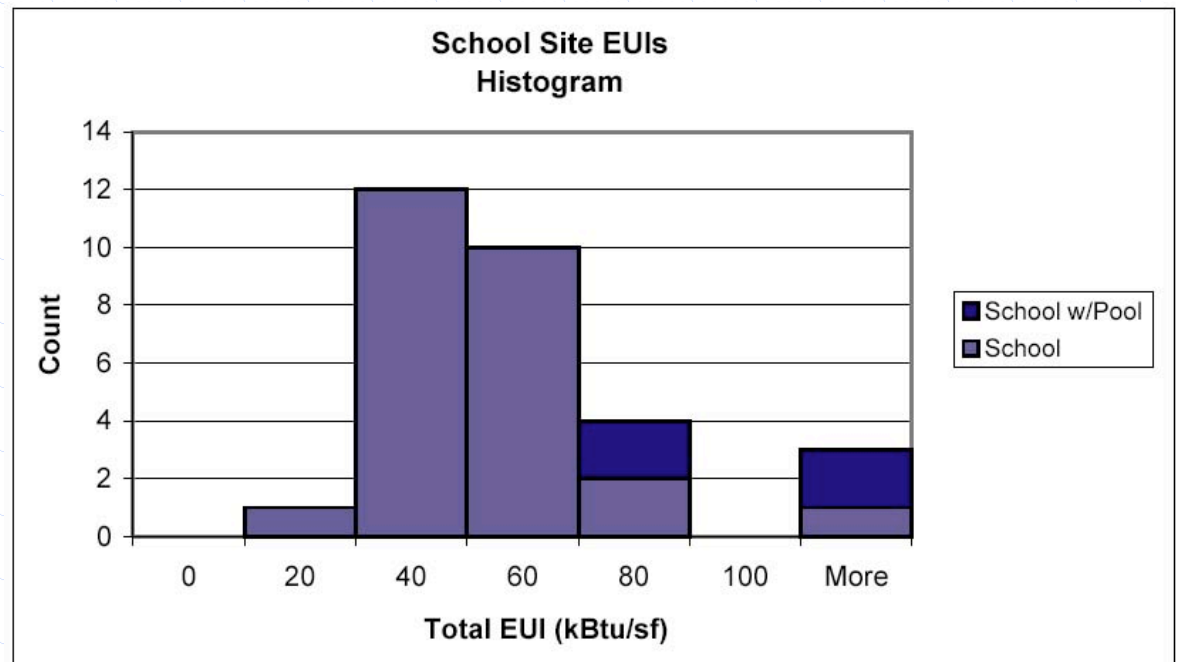
Metrics

Assessment Records Click this button to view and edit Assessment Records for the Objective selected above.

| Index | Metric Name | Metric Description | Target | Units |
|-------|--|--|--------|-------|
| 1 | Total annual kWh/sf | Whole-building electric energy use per gross square foot of building. From building electric meter. | | |
| 2 | Annual source BTU/sf (combined gas and electric) | Whole-building total energy use per gross square foot of building. Source BTU/sf is calculated using XXXX BTU/kWh of electricity and a | | |

Caveats & Pitfalls

- ◆ Intensity does not equal efficiency
- ◆ Hard to avoid apples-and-oranges comparisons (want energy per unit of service)
- ◆ Normalization
 - ✓ weather
 - ✓ floor area
 - ✓ schedule
 - ✓ plug loads
 - ✓ indoor conditions
 - ✓ energy price
 - ✓ more....



Recommendations

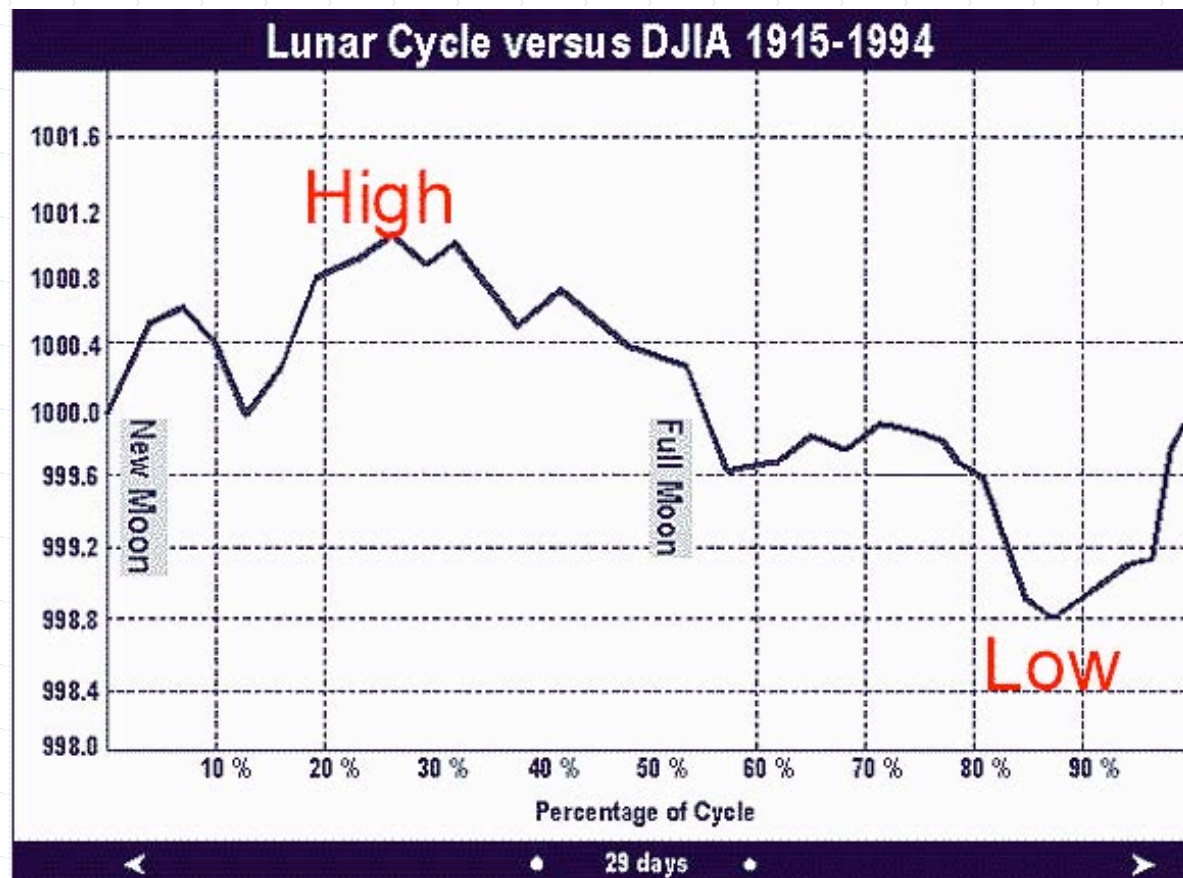
- ◆ Decide how benchmark is to be used
 - √ Choose type(s) of benchmarks
 - √ Define “figures of merit” (metrics)
 - √ Be creative -- think of audience
- ◆ Need practical data collection and analysis strategy
- ◆ Recognize and possibly integrate with existing non-energy benchmarking systems
- ◆ Benchmarking is a one-handed clap
 - √ A means to an end.... What will be done with the information?

Moral of the Story

“To define an energy efficiency indicator is not only a technical challenge, but also a pre-structuring of the subsequent policy choice.”

- Aebischer, et al. (2003)

Correlation is Not Causation!



Advice for Traders: “moon-trading is by no means a stand-alone approach”